FORMULATION OF A VASCULAR TRAUMA SCORING SYSTEM TO PREDICT EXTREMITY SALVAGE AND A CLINICAL COMPARISION STUDY WITH MANGLED EXTREMITY SEVERITY SCORING (MESS)

Dissertation submitted in partial fulfillment of the requirements for the degree of

M.Ch. (VASCULAR SURGERY) Branch III

THE TAMIL NADU DR. M.G.R. MEDICAL UNIVERSITY

CHENNAI

AUGUST 2007

CERTIFICATE

This is to certify that the dissertation titled FORMULATION OF A VASCULAR TRAUMA SCORING SYSTEM TO PREDICT EXTREMITY SALVAGE AND A CLINICAL COMPARISION STUDY WITH MANGLED EXTREMITY SEVERITY SCORE (MESS) submitted by Dr V Anand appearing for M.Ch. Vascular Surgery degree examination in August 2007 is a bonafide record of work done by him under my guidance and supervision .

Professor T Vidyasagaran, M.S.,DNB, M.Ch.(Vascular Surgery), F.I.C.S.
Professor& Head of Department,
Department of Vascular Surgery,
Madras Medical College
Chennai

The Dean
Madras Medical College
Chennai – 600003.

ACKNOWLEDGEMENT

I gratefully and sincerely acknowledge the Dean Madras Medical College, Chennai for granting me permission to utilize the facilities of the institution to pursue this study.

I hereby sincerely wish to express my gratitude to Prof T Vidyasagaran, M.S., DNB, M.Ch. Vascular Surgery, FICS, Professor & HOD Department of Vascular Surgery who with his limitless patience and appropriate guidance helped me in formulation of this dissertation.

I am indebted to my guide Assistant Professor Dr SR Subramanian and other assistant professors Dr N Sritharan, Dr Kamalakannan, Dr Amolorpavanathan, Dr Saravanan, Dr Tulasi Kumar, Dr Ilayakumar who have constantly guided me in the compilation of this dissertation..

I would also like to acknowledge the motivation and encouragement provided by our retd Professor SA Hussain and Dr Rajkumar who with their untiring efforts and invaluable suggestions have helped me in this work. Special mention must be made for the statistician Mrs Basilea Watson, who has helped in compiling the statistics for the dissertation.

Last but not the least I thank the patients who have willingly participated in this study and despite their ailments, placed their faith in us.

CONTENTS

1. MESS 8 MMC 10 AMPUTATED
2. MESS 10 MMC 11 AMPUTATED
3. MESS 7 MMC 8 SALVAGED
4. MESS 7 MMC 8 SALVAGED
5. MESS 8 MMC 10 AMPUTATED
6. MESS 8 MMC 8 SALVAGE
7. MESS 6 MMC 6 SALVAGE
8. MESS 9 MMC 9 SECONDARY AMPUTATION
9. MESS 9 MMC 10 SECONDARY AMPUTATION
10. PREVIOUS CASE - POPLITEAL ANASTOMOSIS
11. PREVIOUS CASE - PTA ANASTOMOSIS
12. EXTRA-ANATOMIC BYPASS TO ULNAR A
13. MESS 5 MMC 6 SALVAGED
14. MESS10 MMC11 AMPUTATION
15. MESS 7 MMC 7 SALVAGED
16. MESS 8 MMC 8 SALVAGED
17. MESS 7 MMC 8 SALVAGED
18. POST-OP EXTRA-ANATOMIC BYPASS WITH SKIN COVER
19. MESS 9 MMC 9 SALVAGED
20. MESS 7 MMC 5 SALVAGED

Introduction

Vascular trauma is a common component of polytrauma and requires prompt recognition, urgent resuscitation, early evacuation to a vascular centre for life and limb salvage. Longer the duration of ischemia, greater is the threat to the limb, increased infection rates and consequently poor outcome of revascularization attempts. This study concentrates on certain limb injuries, which present with crush injury and extensive soft tissue damage, concomitant vascular and/or nerve injury and major bony disruption. During the past few decades, better understanding of the injury itself and technical advances in surgery (allowing revascularization of the extremity, stabilization of the complex fracture, and reconstruction of the soft tissues) and rehabilitation have led to an increased frequency of attempts at limb salvage. In some of these patients, however, limb salvage may have subsequent deleterious results, which is associated with a high morbidity and poor prognosis and often requires late amputation (27 – 70%) despite initial success. In these cases, early or primary amputation might even be beneficial. Attempts to qualify the severity of the trauma and to establish numerical guidelines on whether to amputate or salvage the limb have been proposed by several authors. Published scoring systems of lower extremity injury include the Mangled Extremity Severity Score (MESS), Predictive Salvage Index (PSI), Nerve injury, Ischemia, Soft tissue injury, Skeletal injury, Shock, Age of patient (NISSSA) and Mangled Extremity Syndrome Index (MESI). The developers of these scoring systems attempted to validate them by demonstrating high rates of specificity and sensitivity in predicting limb salvage. However, independent testing of some of these scoring systems has not duplicated the success reported by the developers. It is pertinent to note that although a vascular surgeon is one of the prime determiners of decision taken for limb salvage, there is no vascular scoring system to predict limb salvage

Aim

The aim of this dissertation is to formulate and assess a Vascular Trauma Score, compare the score with Mangled Extremity Severity Score (MESS) and evaluate both to predict limb salvage in patients with vascular injuries.

Patients and methods

This study is an ongoing prospective study being done at a government medical college hospital equipped with all facilities of a tertiary level trauma centre including angiographic, color Doppler, CT, MRI facilities. The study period is over two years. All patients having acute traumatic vascular injuries with or without crush syndromes, bone injuries, nerve, vein injuries have been included. Only extremity injuries to both upper and lower limb have been included. Abdominal, chest vascular injuries have been excluded. Patients with severed limbs, traumatic amputations have been excluded from this study. There was no cut off for duration of ischemia as long as the limb was intact.

Limbs requiring primary amputation as a result of vascular and combined injuries have also been included.

All cases were assessed in trauma ward immediately on reception by orthopedic or general surgeons. Urgent resuscitation was carried out where indicated. Vascular surgical consultation was obtained when vascular injury was suspected. From this stage onwards, vascular surgeons come into the treatment chain and subsequent management is jointly done with orthopedic and plastic surgeons. All patients with suspected vascular injuries were evaluated by a vascular surgeon by a detailed clinical examination, hand held Doppler measurement of flow status and detailed orthopedic and plastic surgical evaluation. Based on clinical parameters, limb salvage was attempted with vascular, orthopedic or plastic surgical reconstruction. All patients with vascular injuries irrespective of whether they were revascularised or primarily amputated were scored with a vascular score formulated, hereafter called MMC (Madras Medical College) score and standard MESS. Scores of limbs salvaged and those who underwent primary or delayed amputation were compared and conclusions drawn. Statistical analysis using ROC curve was done to assess the validity of the score and to predict sensitivity and specificity.

All cases with vascular injuries which have been operated are included in this study. A vascular trauma score developed as below and MESS was applied but decision for primary amputation or attempt at limb salvage was taken ultimately by clinical assessment. Subsequently, patients were followed up post op till limb salvage and discharge or delayed amputation was done. Cases where primary amputation was advised on clinical assessment were also scored to evaluate the accuracy of this score in predicting amputation.

<u>Madras Medical College Vascular Trauma Score</u>

1. Severity of injury

High energy, Severe crush injuries, Missile injuries	3
Low energy, Blunt injuries, Open injury with/ without fractures	2
Puncture wounds, Incised clean wounds	1

2. Duration of ischemia

> 10 hours	3
6 – 10 hours	2
< 6 hours	1

3. Flow on hand held Doppler

No flow	2
Non pulsatile flow	1
Pulsatile flow	0

4. Contamination

Contaminated wounds with obvious dirt, grit particles, road traffic accident wounds, industrial accidents	2
Minimal contamination, clean incised wounds, puncture wounds	1
No external contamination, closed vascular injuries	0

5. Associated injuries

Combined (at least two or all three) Major Nerve, Orthopedic and Venous injuries	2
Major venous or orthopedic or venous injury	1
None	0

Maximum score 12

Minimum score 2

MESS (Mangled Extremity Severity Score)

Johansen et al. 1990

Skeletal/ Soft tissue injury

Low energy (stab, simple #, pistol gunshot wound)	1
Medium energy (open or multiple #s, dislocation)	2
High energy (high speed RTA or rifle GSW)	3
Very high energy (high speed trauma + gross contamination)	4

Limb ischemia (score doubled for ischemia >6 hrs)

Pulse reduced or absent but perfusion normal	1
Pulseless, paraethesias, diminished capillary refill	2
Cool, paralysed, insensate, numb	3

Shock

Systolic BP always >90mm Hg	0
Hypotensive transiently	1
Persistent hypotension	2

Age (years)

<30	0
30-50	1
>50	2

Study design

To salvage each limb clinical evaluation was done at the emergency room by a vascular surgical resident. The component levels of each score were totaled. General operative approach was divided into three phases: (1) reduction and fixation of fractures and dislocations (with priority as determined by vascular surgeon); (2) vascular (arterial and venous) injuries were defined and repaired and; (3) wound management was performed. We amputated only the limbs that we couldn't save, because of severe or life threatening infection and arterial graft failure which we couldn't repair again).

Statistics

To examine the discriminated validity of the injury-severity scores of lower extremity, sensitivity, specificity, and Yourdon's *J* for predicting amputation were calculated. Yourdon's *J* describes a statistics that combines sensitivity and specificity so that $J = 1$ indicates maximum sensitivity and specificity and $J = 0$ indicates no relation between the predicted outcomes of an index and the observed outcomes. The sensitivity is defined as the number of limbs amputated with scores, at or above the threshold, divided by the total number of limbs amputated in post operative period upto two weeks. Specificity is defined as the number of salvaged limbs, with scores below the threshold, divided by the total number of salvaged limbs.

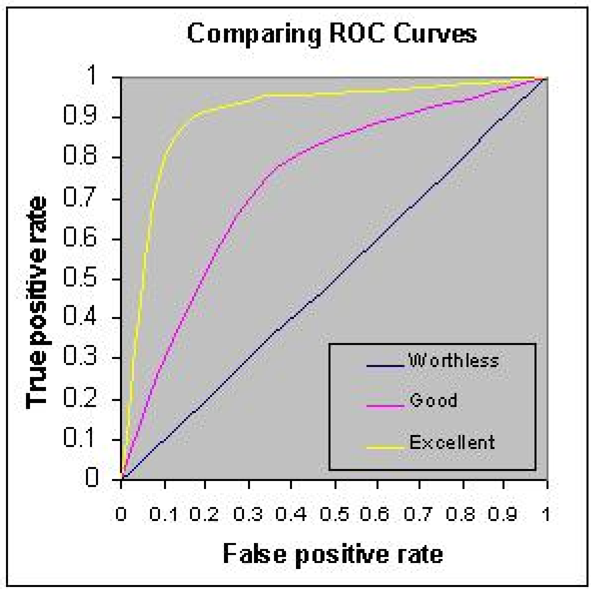
Validity of the scores was done by ROC (Reciever Operating Characteristic) curve. ROC analysis is part of a field called "Signal Dectection Theory" developed during World War II for the analysis of radar images. Radar operators had to decide whether a blip on the screen represented an enemy target, a friendly ship, or just noise.

Signal detection theory measures the ability of radar receiver operators to make these important distinctions. Their ability to do so was called the Receiver Operating Characteristics. It was not until the 1970's that signal detection theory was recognized as useful for interpreting medical test results.

Definition of “ROC curve”

An area of 0.8, for example, means that a randomly selected amputated individual has a score larger than that for a randomly chosen salvaged individual 80% of the time.

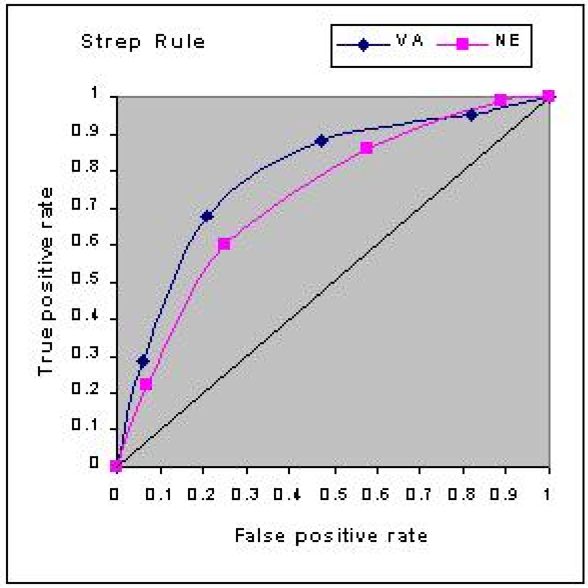
The Area Under an ROC Curve



The graph at right shows three ROC curves representing excellent, good, and worthless tests plotted on the same graph. The accuracy of the test depends on how well the test separates the group being tested into those with and without the disease in question. Accuracy is measured by the area under the ROC curve. An area of 1 represents a perfect test; an area of .5 represents a worthless test. A rough guide for classifying the accuracy of a diagnostic test is the traditional academic point system:

- **0.90-1 = excellent (A)**
- **0.80-0.90 = good (B)**
- **0.70-0.80 = fair (C)**
- **0.60-0.70 = poor (D)**

- **0.50-0.60 = fail (F)**



ROC curves can also be constructed from clinical prediction rules. The graphs at right come from a study of how clinical findings predict strep throat (Wigton RS, Connor JL, Centor RM. Transportability of a decision rule for the diagnosis of streptococcal pharyngitis.(Arch Intern Med. 1986;146:81-83.) In that study, the presence of tonsillar exudate, fever, adenopathy and the absence of cough all predicted strep. The curves were constructed by computing the sensitivity and specificity of increasing numbers of clinical findings (from 0 to 4) in predicting strep. The study compared patients in Virginia and Nebraska and found that the rule performed more accurately in Virginia (area under the curve = .78) compared to Nebraska (area under the curve = .73). These differences turn out not to be statistically different, however.

The area measures discrimination, that is, the ability of the test to correctly classify those with and without the disease. Consider the situation in which patients are already correctly classified into two groups. We randomly pick on from the disease group and one from the no-disease group and do the test on both. The patient with the more abnormal test result should be the one from the disease group. The area under the curve is the percentage of randomly drawn pairs for which this is true (that is, the test correctly classifies the two patients in the random pair).

Computing the area is more difficult. Two methods are commonly used: a non-parametric method based on constructing trapeziods under the curve as an approximation of area and a parametric method using a maximum likelihood estimator to fit a smooth curve to the data points. Both methods are available as computer programs and give an estimate of area and standard error that can be used to compare different tests or the same test in different patient populations.

Review of literature

The injury-severity scores of injured extremities were developed to assist the surgeon in making the initial decision on whether to salvage or amputate an injured limb. Ideally, a trauma limb-salvage index would be 100% sensitive (all amputated limbs with trauma limb-salvage scores at or above the threshold), 100% specific (all salvaged limbs with scores below the threshold), and with Yourden's *J* of 1 (perfect accuracy). With the exception of the MESI and MESS, the developers of the NISSSA and PSI systems considered only lower-extremity injury evaluation. The Mangled Extremity Severity Score (MESS) was proposed by Johansen et al in 1990(1). The MESS was developed retrospectively in a study of twenty five patients. The index was then validated in that same patient group and in a group of twenty-six additional limbs that were assessed prospectively. Johansen et al concluded that a MESS score of 7 or more was 100% predictive of amputation. The performance of MESS did not duplicate these findings in many subsequent series. The significance of correlation between this scoring system and fate of the limb was better than other scoring systems except for the modified NISSSA.

McNamara et al (2) introduced the nerve injury, ischemia, soft-tissue injury, skeletal injury, shock, and age of patient score (NISSSA score) in 1994, to address perceived weaknesses of the MESS. The authors envisioned an application similar to that of the MESS, at the time of initial limb evaluation and clinical decision-making. Specifically, the NISSSA added a nerve-injury component, giving the highest weight to the loss of plantar sensation, and divided tissue injury into soft and skeletal variables. Twenty-six limbs were scored retrospectively with the MESS and NISSSA methods.

Compared with the MESS score, the NISSSA score was found to be more sensitive (81.8% versus 63.6%) and more specific (92.3% versus 69.2%). Both scores were reported to be highly accurate in predicting amputation.

Other Limb Scoring Systems

a. MESI (Gregory) (3)

-A MESI score less than 20 suggested functional limb salvage could be expected, and a score of greater than 20 was associated with an improbable limb salvage and ultimate amputation.

FACTORS POINTS

Injury severity score 1-3

Skin damage 1-3

Nerve damage 1-3

Vascular injury 1-4

Bone injury 1-8

Lag time 1 point for every hour > 6 hrs

Age of patient 1-3

Pre-existing disease 0-1

Shock 0-2

b. Predictive salvage score based on a review of 21 patients with combined orthopedic and vascular trauma (Howe) (4)

-Total score greater than 8 points, amputation was preferred to salvage

FACTORS POINTS

Level of arterial injury 1-3

Degree of bone injury 1-3

Degree of muscle injury 1-3

Interval from injury until arrival in the operating room 0-4

c. Predictive salvage score based on a review of 35 patients (Pozo)

-The patient with an injury score of 8 or greater was unlikely to salvage a useful lower limb

FACTORS POINTS

Skin damage or loss requiring a major skin graft of flap 2

Bone injury with marked comminution or bone loss 2

Muscle damage requiring excision of muscle or tendon 2

Vascular damage involving femoral, popliteal, or both tibial arteries 2

Nerve damage involving the sciatic or posterior tibial nerve 2

Wound contamination 2

d. Limb Salvage Index (LSI) (Russell)

-In 70 limbs studied, 51 patients with an LSI score of less than 6 had successful limb salvage, and all 19 patients with an LSI score of 6 or greater had amputations

FACTORS POINTS

Arterial injury 0-2

Nerve injury 0-2

Bone injury 0-2

Skin injury 0-2

Muscle injury 0-2

Vein injury 0-1

Warm ischemic time 0-4

Criticisms of scoring systems as per the authors are :-

-observer error

-often no reference to other life threatening multi-system injuries

-not all take into account the site of injury (proximal/distal)

-do not differentiate by mechanisms of injury (weapons/MVA/fall)

-often do not address long-term function

-use of the scores may complicate or even precipitate medico legal issues

Between December 2000 and August 2003, a prospective study on all patients with arterial injuries in mangled extremities was undertaken. All patients were scored using the MESS and the Mangled Extremity Severity Index (MESI). During this period, arterial reconstruction was performed in 62 patients. Primary patency, secondary patency, and limb salvage rates were 81%, 85.5%, and 93.5%, respectively. The only factor affecting limb salvage (statistical trend) was the site of trauma (upper limb 100% vs lower limb 89%; $p = .08\%$). There was no significant effect related to the mechanism of trauma (blunt 90% vs stab 100%; $p = .125$), MESS (< 7, 100% vs > 7, 91%; $p = .22$), and MESI (< 20, 100% vs > 20, 90.5%; $p = .154$). Upper limb injuries were the least likely to lead to amputation. They recommend that all injuries, whatever their score, should be surgically explored before treatment decisions are made.

In another Indian study at PGI Chandigarh, Menakuru SR et al (6) studied 148 patients with vascular trauma over 6 years and concluded that had the recommendations of MESS been applied, the salvageability rate would be lesser than what was achieved. They opined that MESS had low sensitivity and specificity. The management of lower extremity trauma with vascular involvement should be directed toward to the salvage of the extremity or to the primary amputation according to the additional pathologies, parameters of the patient and the extremity.

Tornetta P, Olson SA (7) opined that the decision to attempt salvage or to amputate a severely injured leg in among the most difficult that the orthopaedician must face. Even surgeons with tremendous trauma experience cannot agree on standard course of action. In the face of such injuries, physician consultation regarding the treatment decision, including all of those members of the team that are needed for a successful salvage, is necessary. In the best circumstances, the trauma surgeon, vascular surgeon, orthopaedician and a soft-tissue specialist are all involved. The timing of an amputation is important. Although each patient's case is unique, immediate amputation is often viewed by the patient and family as a result of the injury. Conversely, a delayed amputation may be viewed as a failure of treatment. Scoring systems are of some help in estimating the chances of a successful salvage. However, the ultimate decision to amputate or attempt salvage is based on such patient factors as preinjury function and social situation, and of associated injuries, surgeon experience, available resources, projected physical abilities, and the patient's projected physical requirements.

Bonnani F et al (8) in their study on 58 lower limb salvage attempts over a 10-year period retrospectively scored using the Mangled Extremity Syndrome Index

(MESI), Mangled Extremity Severity Score (MESS), Predictive Salvage Index (PSI), and the Limb Salvage Index (LSI). Primary amputations were excluded. Limb salvage failure was defined at four levels, including functional failure 2 years post injury. Cross-validational sensitivity and specificity analyses revealed no predictive utility in any of the four indices. Although most failed limb salvage attempts could be identified early in the course of management, a significant percentage of their patients suffered prolonged reconstructive efforts. So they conclude that efforts must be directed at more precisely determining the factors that avoid futile salvage efforts.

Durham BR (9) assessed the role of scoring systems as predictors of amputation and functional outcome in severe blunt extremity trauma was examined. All severe extremity injuries treated over a 10-year period were scored retrospectively using four scoring systems: Mangled Extremity Syndrome Index (MESI), Mangled Extremity Severity Score (MESS), Predictive Salvage Index (PSI), and Limb Salvage Index (LSI). Twenty-three upper and 51 lower extremity injuries were evaluated. Sensitivity and specificity, respectively, were MESI 100% and 50%, MESS 79% and 83%, PSI 96% and 50%, and LSI 83% and 83%. For each system, there were no differences between patients with good and poor functional outcomes. They concluded that all of the scoring systems were able to identify the majority of patients who required amputation. However, prediction in individual patients was problematic. None of the scoring systems were able to predict functional outcome.

Saulterbeck JR et al (10) state that the MESS is a scoring system that can be applied to mangled extremities and help one determine which mangled limbs will eventually come to amputation. The records of 37 patients having sustained 43 open fractures or mangled upper extremity injuries, seen and treated at the University of New Mexico's Regional Trauma Center between April 1987 and September 1990, have been reviewed. All nine extremity injuries with a MESS of greater than or equal to seven were amputated, and 34 of 34 with a MESS of less than seven were salvaged. Nine Grade IIIC and six mangled extremities were identified in their study. Five of the Grade IIIC and four of the mangled extremities with a MESS of greater than or equal to seven were amputated. All Grade IIIC or mangled extremities with a MESS of less than seven were salvaged. In conclusion, the MESS is an early and accurate predictor for identifying the extremities that may be best treated by amputation.

Gregory RT et al (11) in their study defined criteria for a "mangled extremity”. Complex injuries with extensive soft tissue, bony injury and nerve damage as well are termed as mangled extremities. Sixty consecutive trauma patients with severely injured extremities during 3 years were reviewed. Seventeen patients fit the category of Mangled Extremity Syndrome (M.E.S.). Injuries were retrospectively classified using a graduated grading system directed at four major tissue systems of the extremity involved (integument, nerve, artery, and bone). Additional scoring items were included to define the significance of trauma sustained outside the extremities. Patients who ultimately came to amputation could have been identified preoperatively at initial emergency evaluation utilizing this graduated grading system. Retrospective data suggest that a Mangled Extremity Syndrome Index (M.E.S.I.) of 20 is the dividing line below which functional limb salvage can be expected and above which limb salvage is improbable. Prospective application of this system, as well as an organized multidisciplined approach, could be useful in the identification of functionally retrievable versus probably irretrievable extremities, thus identifying and helping define the indications for amputation. The grading system criteria and results in these 17 patients form the basis of this report.

Severe injuries require a coordinated approach to assure functional salvage and decisions regarding amputation require careful judgement. These decisions cannot and often do not have to be made upon initial presentation but the patients and their families need to be prepared for the rigorous task of salvage or ablation as the situation dictates. The process of limb salvage entails anatomic replantation as well as functional restoration and this will comprise on an average eleven months and seven surgical procedures. Unfortunately, not every salvaged limb becomes functional to the patient's satisfaction and late amputations occur in approximately 19%. Functional and social reintegration appears to be dependent on severity of the soft tissue injury.

The patients that produce the decision-making dilemma are those with significant injuries or injury to the lower extremity yet has a viable foot, and the prognosis for a functional limb is so poor that primary amputation is indicated, but oftentimes not performed during their primary hospitalization. However, the topic would not be adequately covered without a clear understanding that limb salvage is not for everyone with a mangled extremity. The physiologic toll that the body takes while undergoing limb salvage is enormous, not to mention the psychological and financial burden that accompanies the process of useful limb salvage. Limb salvage patients will have longer hospitalizations, more complications and greater long-term disability. Data still support the aggressive limb salvage treatment for the younger patients, as total societal costs are less over the working lifetime of the individual.

Even today the majority of clinical decision making is subjective about limb salvage. There are objective criteria for assisting the clinician with the vigorous task of deciding functional limb salvage (Table 1).

Table 1. Criteria For Deciding Limb Salvage
I. Wounding Local, sharp ; Wide, crush Soft tissue & Skeletal Injury * Mechanism of injury * Extent of contamination * Degree of periosteal stripping **II. Neurologic Function** Presence of functioning posterior tibial nerve **III. Ischemia** Degree and Duration of Ischemia 6 hour "golden period" **IV. Systemic Response** Shock Associated injuries producing shock Associated injuries precluding early care to limb

V. Age

50-year-old physiology and wound healing response differs from that of a younger individual. The average age of trauma population being 17, 35 and 50 years old patients are 2 standard deviations from the median age.

The various predictive scoring schemes are all based on the assessment of the data in Table 1 and are weighted based on the impact that each variable would have on eventual outcome.

Limbs with extensive crushing to the soft tissue elements (muscle) although salvaged as an appendage may not function as desired or may be dysfunctional and neuropathic. Large zones of crush injury are predisposed to higher rate of infection due to the concomitant muscle hypoxia and secondary necrosis that develops. No antibiotic regimen has been shown to affect the infection rate of this type of injury induced infection. The timely removal of all dysvascular and avascular tissue is the only proven prophylactic maneuver.

The quantity of muscle that can be debulked and still maintain a functional limb varies with the preinjury muscle mass, and the presence of injuries that may prevent normal ankle motion. Large zones of injury of this nature often develop secondary problems as the injury evolves over time. For example, the crushed limb with a proximal arterial injury is revascularized in a timely manner. However the zone of injury being large required a lengthy interposition graft. Although the distal limb is now adequately perfused and by all accounts the procedure is successful the intercalary zone of injury is now bypassed by the interposition graft and hence has no blood supply in that region as previously supplied by the local muscle branches. This scenario has been coined the "Interstate syndrome" as the blood supply has rapid flow to the foot, but no off ramps to the nutrient vessels along the way, and like the small towns along thruways the muscle begins to die, and fibrose over time. We presently do not have the technical ability to successfully revascularize individual muscles within the zone of injury, and the avascular zones now also contribute to the delayed union or nonunion of the skeletal injury. Nonunion and infected nonunion of the skeletal injury was a major reason for many delayed amputations. The insight to predict this type of outcome is necessary to prevent the commitment of resources to a project that is doomed to fail.

The first order of care is to determine what treatment is best suited for the individual and finally the individual injury itself. Patients with multiple system involvement (Injury Severity Score > 25) often simply cannot withstand the persistent toxic load that a mangled extremity presents to them without exacting a toll on the overall system. Early amputation therefore is part of the life saving process that must be considered even though the limb may be potentially salvageable.

Often the surgical exercises of limb salvage are needed to restore function to the limb without the limb ever being at risk from a physiologic standpoint. A typical example of this would be the young laborer who presents with a large crushing mechanism and a resultant wedge type fracture of the tibia and fibula. Although the skin envelope is intact, the injury itself carries the same prognosis as an open (Gustilo type III A) fracture. Therefore the treatment scenario is essentially that of limb salvage if one wants to restore maximum function.

In a study by Faris IB (12) performed to identify the factors associated with amputation in patients with blunt injuries to the lower limb associated with arterial injury. The ability of a scoring system to predict the outcome was tested. There were 122 lower limb arterial injuries in 119 patients treated at the Royal Adelaide Hospital in the years 1962-1994. Prognostic factors considered were the site of the injury, the severity of the soft-tissue injury and shock, the presence of associated injuries and a description of the bone or joint injury. The MESS was calculated retrospectively for each patient. The outcome was primary amputation in 27 patients, delayed amputation in 36 patients and limb salvage in 59 patients. The seven deaths were all due to associated injuries. Factors associated with amputation were the severity of shock and soft-tissue injury ($P < 0.01$), and tibial artery injury compared with more proximal injury ($P < 0.001$). Factors that did not affect outcome included delay before repair, method of fracture fixation, or performance of fasciotomy. Amputation was performed in 48/71 (68%) patients with Gustilo type-IIIC fractures of the tibia. Applying the MESS to our patients resulted in a positive predictive value (PPV) of 71%, a negative predictive value (NPV) of 84% and an overall accuracy of prediction of 75%. The major factor determining outcome was the severity of the soft-tissue injury. Progressive necrosis and infection was a major cause of late amputation. The MESS is not sufficiently precise to allow the decision regarding amputation to be made at the initial operation.

Lazarides MK et al (13) from Department of Vascular Surgery, Athens General Hospital, Greece published the records of 18 consecutive patients with popliteal and/or trifurcation civilian arterial injuries, who underwent revascularisation procedures during a 5-year period, were retrospectively assessed. All patients were classified using four, previously described, severity scoring systems in an effort to investigate the accuracy of predicting the outcome of this type of injury. The amputation rate in this group was 28%. Limbs which could not be salvaged were all in the "trifurcation" group and in this subset of patients the amputation rate was 71% (5/7). The scoring index having the higher overall accuracy (94%) was the mangled extremity syndrome index (MESI) with a predictive value for amputation of 83%. The use of these indices as criteria for primary amputation needs further evaluation as no scoring system was specific enough to permit primary amputation on that basis alone. The predictive value for limb salvage was 100%, for all four scoring systems enabling their use in vascular trauma audit.

Samuel G. Agnew, M.D., F.A.C.S. in an article titled A New Definition Lower Extremity Limb Salvage**:** Decision Making & Technical Challenges (14), states that limb salvage was previously considered successful if the anatomic structure was retained and viable. Function and patient satisfaction are equally important parameters to contend with. The rate of secondary amputation for lower limb injuries undergoing limb salvage averages 25% within the first two years after seemingly successful limb salvage. Limb salvage in the era of cost containment and limited resources will entail restoration of function and limited disability and improved patient satisfaction, a daunting task to say the least. The success of limb salvage surgery is squarely on the shoulders of the physician and our ability to convey the realities of the salvage process to our patients such that unrealistic expectations do not cause early psychologic failures.

As per practice parameter for evaluation and management of combined arterial and skeletal extremity injury from penetrating trauma (15):-

Primary amputation should be considered in those with tibial or sciatic nerve transection, prolonged ischemia, massive soft tissue injury, severe contamination, open comminuted tibia-fibula fractures (Gustilo-III), or life-threatening associated injuries. Mangled extremity scoring systems are not sufficiently reliable to serve as the sole determinant of extremity amputation. Combined extremity vascular injuries are relatively uncommon, making up only 0.2% of all civilian trauma. Only 1.5% to 6.5% of all extremity skeletal injuries are associated with an arterial injury, while 20% to 73% of all extremity arterial injuries may be associated with skeletal fractures or dislocations. Blunt trauma is the predominant mechanism for these injuries in most civilian series. However, over the last decade penetrating trauma has increased in its incidence in this setting, forming 24% to 71% of cases. It is clear that combined extremity injuries pose a substantially increased risk of limb loss and limb morbidity than do isolated or skeletal extremity injuries. This is most likely due to greater disruption of collaterals, soft tissues and nerves. Combined injuries from penetrating trauma have a substantially lower amputation rate than those from blunt trauma in the civilian sector. Five civilian series over the past decade have reported the highest proportions of penetrating trauma as a cause of these complex injuries in the literature, being 50%, 57%, 67%, 71% and 100%. Their combined results show a total of 39 amputations among 228 patients (17%), but only 9 amputations among the 147 patients (6%) with penetrating trauma. In three of these series reporting 88 patients with penetrating combined injuries there were remarkably no amputations. The apparent increasing trend in penetration as the etiology of these injuries in recent years may have made in of itself a substantial contribution to reducing limb loss. It should be noted that three recent series of combined extremity trauma showed either no difference in amputations between blunt and penetrating trauma or a higher amputation rate among the penetrating injuries. However, these series involved small numbers (40 cases) of especially severe injuries. Nonetheless, they demonstrate that there are still other variables which affect outcome besides mechanism. Prompt diagnosis of vascular injury in any injured extremity is essential because of the well established direct relationship between the time interval from injury to treatment and the chance of limb loss. This principle is confirmed by several series which cite prolonged ischemia, delay in restoration of blood flow, or failure of vascular repair as the most common reasons for limb loss in combined arterial and skeletal extremity injuries.

Studies have shown that restoration of blood flow within six hours, both with and without skeletal injury significantly improves limb salvage. There are studies which fail to show a clear correlation between time delay and outcome and some with average treatment delays in excess of eight hours which report amputation rates equivalent to those with prompt treatment within six hours. This again stresses that multiple variables affect outcome, and they cannot be controlled in retrospective reports. However, the weight of evidence indicates that rapid diagnosis must be followed as expeditiously as possible by restoration of blood flow.

Early amputation may sometimes provide better long term outcome, in terms of cost and function, than overly extensive attempts at limb salvage. Gustilo III-C injuries (open comminuted tibia-fibula fractures with arterial injury), sciatic or tibial nerve transection, severe prolonged ischemia, older age with comorbidity, multiple long bone fractures, crush or extensive soft tissue trauma and severe contamination are factors predicting a high rate of amputation. Although several scoring systems for predicting the need for early amputation have been proposed, none have yet shown sufficient prospective reliability to permit a firm decision for amputation. Initial revascularization and skeletal stabilization should be done in most cases before a decision is made.

Snyder WH (16) reviewed 110 popliteal artery injuries over 14 yrs, 75% from penetrating trauma , 57 (52%) with combined injuries though not clear how many combined injuries were from penetrating mechanism. Revascularization was always done first -only 2/29 (7%) were disrupted during subsequent skeletal repair, but rapidly corrected w/o morbidity. Shunt was first for unstable fractures, then external fixation, then definitive vascular repair. Only two amputations (9%) were reported in penetrating group. Fasciotomy should be done liberally before vascular repair. All amputations were in limbs presenting with severe ischemia, delayed diagnosis & treatment.

Mohsen Karami, MD of Sina Spine and Orthopedics Research Center
Sina Hospital(17), in his paper states that the injury-severity scores of injured extremities were developed to assist the surgeon in making the initial decision on whether to salvage or amputate an injured limb. Ideally, a trauma limb-salvage index would be 100% sensitive (all amputated limbs with trauma limb-salvage scores at or above the threshold), 100% specific (all salvaged limbs with scores below the threshold), and with Yourden's J of 1 (perfect accuracy). Few clinical tests are performed ideally. With the exception of the MESI and MESS, the developers of the NISSSA and PSI systems considered only lower-extremity injury evaluation. In this study, they modified PSI and NISSSA so that these scores could be used for upper and lower extremity injury. Modified NISSSA score

and then MESS had a high specificity and sensitivity in predicting fate of severely open tibial fractures and other lower and upper extremity injuries.

Sharma S et al (18) in their study state that amputation of a mangled extremity is repugnant to the patient and the surgeon. However, prolonged unsuccessful attempts at salvage are costly, highly morbid and sometimes lethal. Much discussion has taken place regarding which criteria predict successful salvage, and predictive indices have been proposed in an attempt to identify limbs for which attempted salvage is unlikely to succeed. The MESS system is the most thoroughly validated of the various classification systems, but at present there is no predictive scale that can be used with confidence to determine whether to amputate or attempt to salvage a mangled lower extremity. Keeping in view the paucity of studies on Indian patients, a prospective trial of MESS was done in 50 patients who had 56 mangled extremities during the last 3 years. A significant difference between the MESS value of salvaged limbs (4.7) and amputated limbs (8.6) was found. MESS value of more than 7 was most specific and was found to have a positive predictive value of 100%. The results have been compared with Western literature and authors suggest that nerve injuries and irreparable soft tissue loss should be given an extra point each. In bilateral cases, the MESS value of each limb should be properly assessed (especially when patient is in shock), as the score may increase because of the other injured limb.

Ozal, Gulhane et al (19) in their study propose that the management of lower extremity trauma with vascular involvement should be directed toward to the salvage of the extremity or to the primary amputation according to the additional pathologies, parameters of the patient and the extremity. They investigated the efficiency of MESS, which is proposed as a grading system to evaluate the change to extremity salvage or the risk for onset of systemic complications. 81 patients with lower extremity trauma were analyzed according to MESS criteria. 79 of the patients were men and mean age was 23 +/- 4. Fourteen patients had higher MESS score. (MESS > 7). Seven of them were older than 50 years. Primary amputation was performed in four of these 7 patients. Vascular repair was performed in three of patients. Multiorgan failure was developed in two of them and both patients died. Secondary amputation was performed to another patients underwent vasculary repair who had MESS > 7 score. Primary amputation was not performed directly in young patients who had MESS > 7. Secondary amputation was required in two of these patients. MESS scoring system can easily predict amputation in older patients but may cause unnecessary amputation in young patients

Bosse et al (20) in a multicenter prospective study was designed to evaluate treatment and outcomes following high-energy lower extremity trauma. All patients were examined on admission, and the injury was characterized according to the Gustilo, Tscherne and the AO classification of soft tissue injuries. All fractures were classified using the OTA fracture compendium. Each patient had the components of the Mangled Extremity Severity Score (MESS), the Predictive Salvage Index (PSI), Limb Salvage Index (LSI), and the NISSSA recorded at the time of initial evaluation. Surgeons were also asked at the time of initial evaluation to rank order multiple injury and patient characteristics as to their importance in making the decision to salvage or amputate. Lastly, the surgeon recorded the degree of participation that the patient, the family and other members of the treating team had in the decision-making process.

A total of 520 patients were enrolled in the Limb Salvage Study. Of these, 248 limbs in 240 patients had Grade IIIB or IIIC tibia fractures. Patients with traumatic amputations (60 legs) were excluded from review; 74 patients underwent amputation during initial hospitalization (66 prior to attempted soft tissue closure and 8 after). The remaining 174 patients proceeded along the reconstruction pathway and were discharged from the hospital without limb amputation. Threshold groupings (above or below) and sensitivity, specificity and positive predictive values of salvage indices are presented in the table.

Score n = 248	Patients >= threshold score	% amputated >= threshold score	% amputated < threshold score	Sensi/Specif for early amputation	Positive Predictive Value
MESS	20.2% (50)	66.0% (33)	20.7% (41)	44.6/90.2%	66.0% (33/50)
PSI	27.0% (67)	58.2% (37)	20.4% (37)	37.8/82.2%	55.2% (37/67)
LSI	19.4% (48)	85.4% (41)	16.5% (33)	55.4/96.0%	85.4% (41/48)
NISSSA	12.5% (31)	90.3% (28)	21.2%(46)	37.8/98.3%	90.3% (28/31)

The decision-making process was heavily influenced by the orthopaedic opinion. In cases selected for limb salvage, the orthopaedic surgeon was listed as "very involved" in the decision process in 98.9% of the cases (general/trauma surgeon = 25.7%, plastic surgeon

= 14%, the patient = 11.7%, and the family = 4.7%). In limbs undergoing amputation, the orthopaedic surgeon was "very involved" in 96% of the cases (general/trauma surgeon = 43.8%, plastic surgeon = 14%, the patient = 21.6%, and the family 21.6%).

This is the first prospective analysis of the published limb salvage indices using a large cohort of patients who were subjected to a prospective data collection process. In this series, they found a low sensitivity and a relatively high specificity across all of the indices. The percent of patients amputated above the various index threshold scores varied from 58% to 90%. Conversely, between 16% and 22% of patients with scores below this threshold also underwent amputation. At this point in time, the data do not support the use of any of the indices to make an acute limb salvage or amputation decision.

The orthopaedic surgeon appears to have the most decisive role in the acute limb salvage decision making process. Factors identified by the orthopaedic surgeon to heavily influence the decision to amputate, in order of preference, were the severity of muscle damage, the presence of a vascular injury and the absence of plantar sensation. Two of these factors (the degree of muscle injury and plantar sensation) were the same factors identified by the regression analysis as significant predictors of limb amputation. Although the analysis predicts the significance of the severity of muscle damage in the limb salvage decision process, neither the MESS nor the NISSSA score this domain. Finally, it must be remembered that the ability to predict limb survival and discharge from the hospital does not equate to a long-term good functional outcome. Correlation of late outcome with the initial limb salvage scores must be determined in order to refine the validity assessment of a scoring system.

Results

In this study, from 2004 to 2007 a total of 112 cases of traumatic vascular injuries of upper and lower extremities were analysed.

Upper limb 53

Lower limb 59

Primary amputation advised in 12 cases UL 03 LL 09

Upper limb

No of Cases with following severity of injury

	Salvaged	Amputated
Mild(score 1)	5 (9.4%)	1(1.8%)
Moderate (score2)	37(69.7%)	-
Severe(score3)	5(9.4%)	5(9.4%)

χ^2 value = 22.6; p-value = 0.00

No of cases with Duration of ischemia <6 hrs

6 - 10

>10 hrs

	Salvaged	Amputated
<6 hrs (score 1)	14(26.3%)	-
6-10 hrs(score2)	20(37.7%)	1(1.8%)
>10 hrs(score3)	13(24.4%)	5(9.4%)

χ^2 value = 8.6; p-value = 0.07

No of cases with

Pulsatile flow

Non pulsatile flow

No flow on hand held doppler

	Salvaged	Amputated
Pulsatile flow(score 0)	8(15%)	1(1.8%) -
Non pulsatile flow(score1)	26(49%)	-
No flow(score2)	13(24.4%)	5(9.4%)

χ^2 value = 8.9 ; p-value = 0.06

No of cases with

Gross Contamination

Minimal contamination

Closed wounds

	Salvaged	Amputated
Closed Wound (score 0)	7(13.2%)	-
Minimal contamination(score1)	29(54.6%)	2(3.7%)
Gross contamination(score2)	11(20.7%)	4(7.5%)

χ^2 value = 10.7; p-value = 0.03

No of cases with

+nerve+vein injury

#/N/Vein inj

	Salvaged	Amputated
No associated injury (score 0)	8(15%)	-
#/N/Vein(Isolated) injury(score1)	32(60.3%)	1(1.8%)
# + N + Vein(any two or all three) contamination(score2)	7(13.1%)	5(9.4%)

χ^2 value = 14.8; p-value = 0.005

Lower limb

No of Cases with following severity of injury

	Salvaged	Amputated
Mild(score 1)	4 (6.7%)	-
Moderate (score2)	23(38.9%)	6(10.1%)
Severe(score3)	5(8.3%)	21(35.5%)

χ^2 value = 25.9; p-value = 0.00

No of cases with Duration of ischemia <6 hrs

6 - 10

>10 hrs

	Salvaged	Amputated
<6 hrs (score 1)	8(13.3%)	-
6-10 hrs(score2)	12(20.2%)	4(6.7%)
>10 hrs(score3)	12(20.2%)	23(38.9%)

χ^2 value = 15.3; p-value = 0.004

No of cases with

Pulsatile flow

Non pulsatile flow

No flow on hand held doppler

	Salvaged	Amputated
Pulsatile flow(score 0)	10(16.9%)	-
Non pulsatile flow(score1)	14(23.6%)	5(8.4%)
No flow(score2)	8(13.3%)	22(37.2%)

χ^2 value = 26.1; p-value = 0.00

No of cases with

Gross Contamination

Minimal contamination

Closed wounds

	Salvaged	Amputated
Closed Wound (score 0)	3(4.9%)	2(3.3%)
Minimal contamination(score1)	26(43.9%)	8(13.5%)
Gross contamination(score2)	3(4.9%)	17(28.8%)

χ^2 value = 20.1; p-value = 0.00

No of cases with

+nerve+vein injury

#/N/Vein inj

	Salvaged	Amputated
No associated injury (score 0)	5(8.3%)	1(1.6%)
Fracture/Nerve/Vein injury(score1)	23(38.8%)	7(11.8%)
Combination of #,Nerve and vein(score2)	4(6.6%)	19(32.2%)

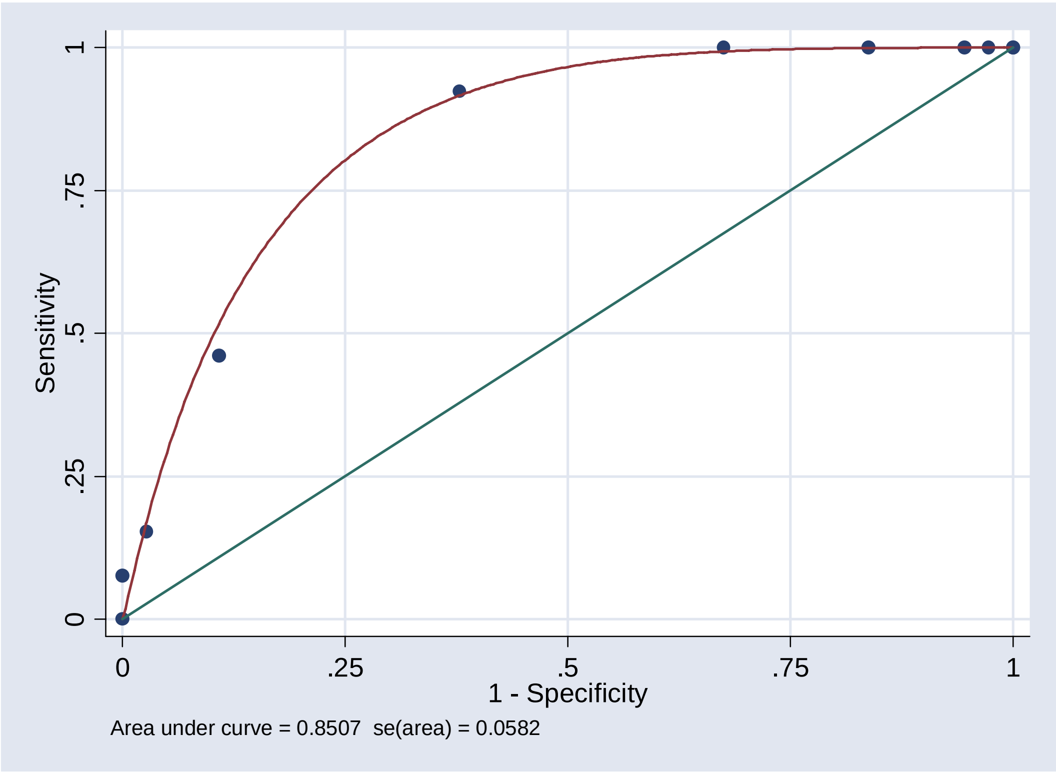
χ^2 value =21.1; p-value = 0.00

Intra-class correlation coefficient

The intra-class correlation coefficient (ICCs) between the MMC and MESS scores were 0.67 (95% C.I.: 0.48, 0.80) for Upper Limb and 0.72 (95% C.I.: 0.55, 0.83) for lower limb.

Upper Limb

ROC curve for the MMC score



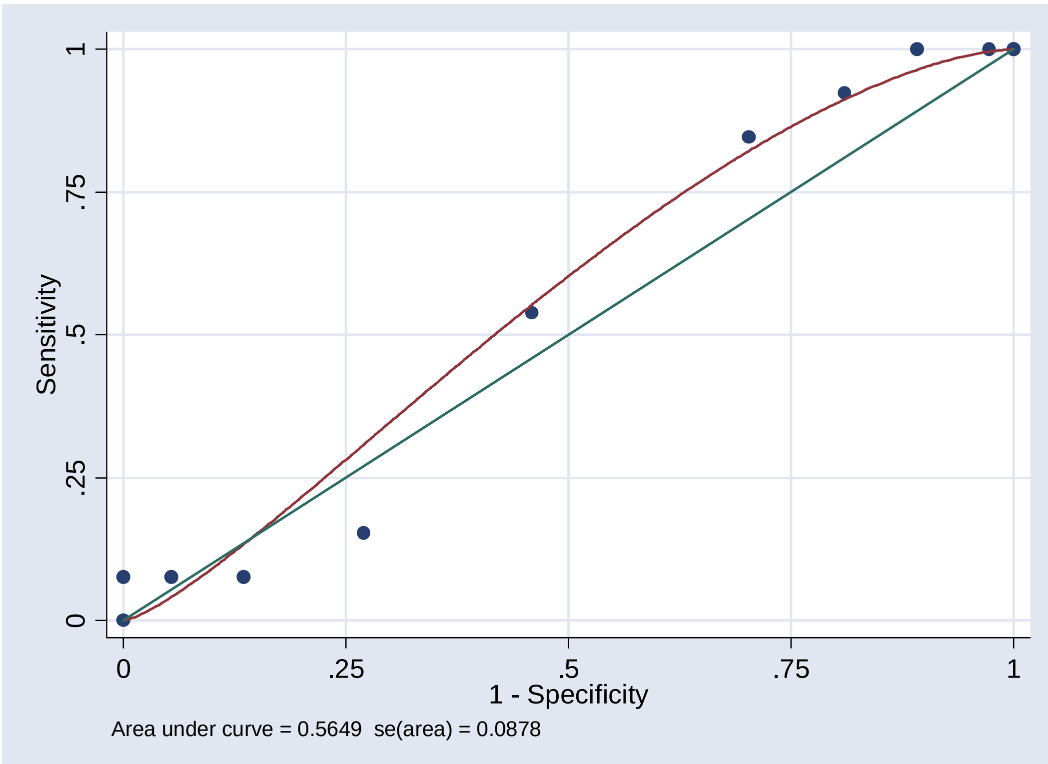
Detailed report of Sensitivity and Specificity

Cut point	Sensitivity	Specificity	Correctly Classified	LR+	LR-
(>= 3)	100.00%	0.00%	26.00%	1.0000	
(>= 4)	100.00%	2.70%	28.00%	1.0278	0.0000
(>= 5)	100.00%	5.41%	30.00%	1.0571	0.0000
(>= 6)	100.00%	16.22%	38.00%	1.1935	0.0000
(>= 7)	100.00%	32.43%	50.00%	1.4800	0.0000
(>= 8)	**92.31%**	**62.16%**	**70.00%**	**2.4396**	**0.1237**
(>= 9)	46.15%	89.19%	78.00%	4.2692	0.6037
(>= 10)	15.38%	97.30%	76.00%	5.6923	0.8697
(>= 11)	7.69%	100.00%	76.00%		0.9231
(> 11)	0.00%	100.00%	74.00%		1.0000

Yourden’s J = Sensitivity + specificity -1 = 0.54

For upper limb MMC score at >8 indicates a high sensitivity and specificity for amputation

ROC curve for the MESS score



Detailed report of Sensitivity and Specificity

Cut point	Sensitivity	Specificity	Correctly Classified	LR+	LR-
(>= 2)	100.00%	0.00%	26.00%	1.0000	
(>= 3)	100.00%	2.70%	28.00%	1.0278	0.0000
(>= 4)	100.00%	10.81%	34.00%	1.1212	0.0000
(>= 5)	92.31%	18.92%	38.00%	1.1385	0.4066
(>= 6)	84.62%	29.73%	44.00%	1.2041	0.5175
(>= 7)	**53.85%**	**54.05%**	**54.00%**	**1.1719**	**0.8538**
(>= 8)	15.38%	72.97%	58.00%	0.5692	1.1595
(>= 9)	7.69%	86.49%	66.00%	0.5692	1.0673
(>= 10)	7.69%	94.59%	72.00%	1.4231	0.9758
(>= 11)	7.69%	100.00%	76.00%		0.9231
(> 11)	0.00%	100.00%	74.00%		1.0000

Yourden's J = Sensitivity + specificity -1 = 0.08

Comparison of Area under the curve (AUC) between the two curves

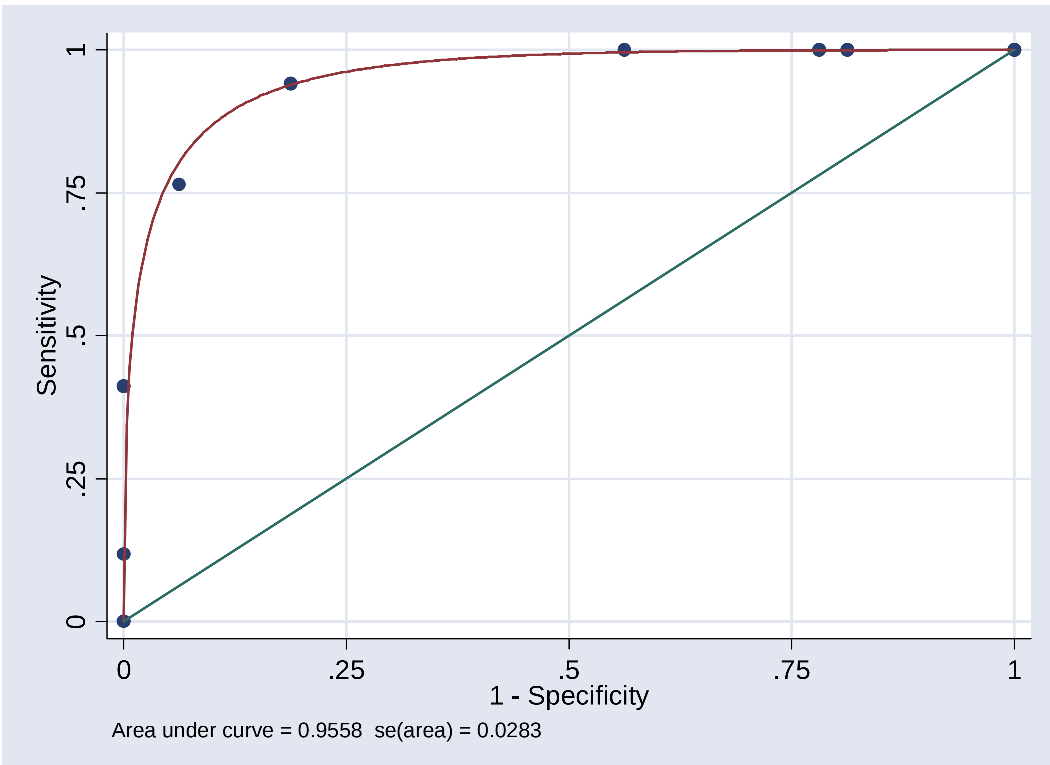
	Obs	ROC Area	Std. Err.	-Asymptomatic Normal-- [95% Conf. Interval]	
UL_MESS	50	0.5416	0.0850	0.37503	0.70813
UL MMC	50	0.8254	0.0564	0.71491	0.93581

Ho: area(UL MESS) = area(UL MMC)

chi2(1) = 12.43 Prob>chi2 = 0.0004

Lower Limb

ROC curve for the MMC score



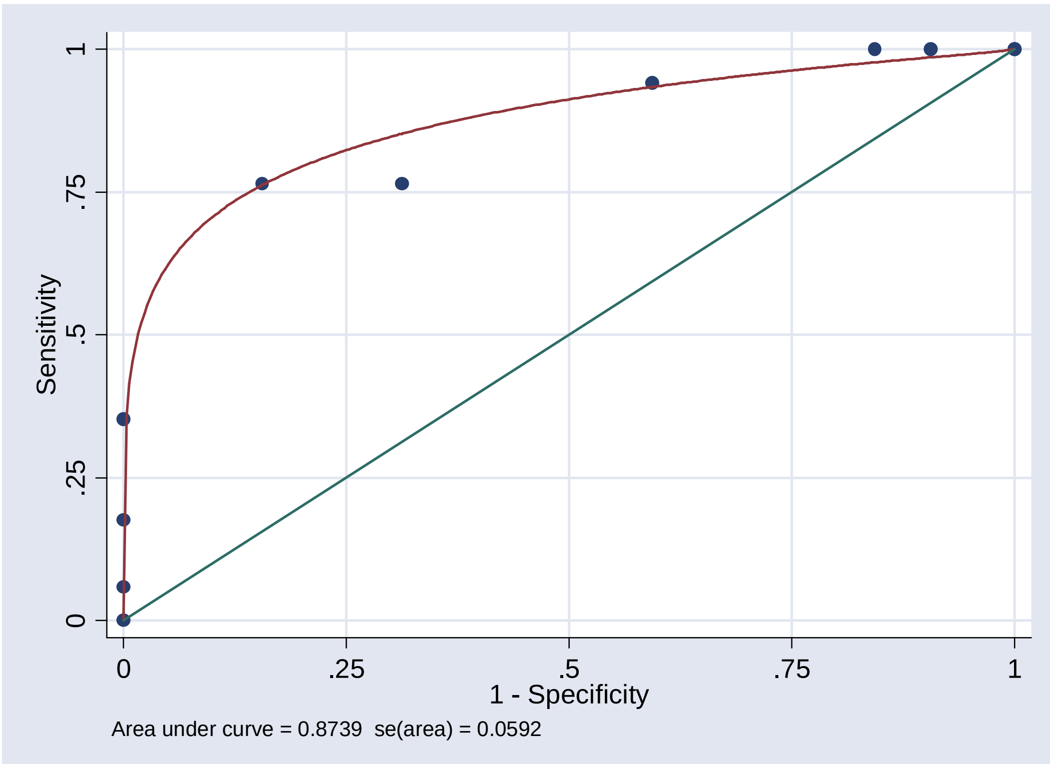
Detailed report of Sensitivity and Specificity

Cut point	Sensitivity	Specificity	Correctly Classified	LR+	LR-
(>= 5)	100.00%	0.00%	34.69%	1.0000	
(>= 6)	100.00%	18.75%	46.94%	1.2308	0.0000
(>= 7)	100.00%	21.88%	48.98%	1.2800	0.0000
(>= 8)	100.00%	43.75%	63.27%	1.7778	0.0000
(>= 9)	**94.12%**	**81.25%**	**85.71%**	**5.0196**	**0.0724**
(>= 10)	76.47%	93.75%	87.76%	12.2353	0.2510
(>= 11)	41.18%	100.00%	79.59%		0.5882
(>= 12)	11.76%	100.00%	69.39%		0.8824
(> 12)	0.00%	100.00%	65.31%		1.0000

Yourden’s J = Sensitivity + specificity -1 = 0.75

For lower limb at MMC score of 9 is the cut off for predicting amputation with a high degree of sensitivity and specificity

ROC curve for the MESS score



Detailed report of Sensitivity and Specificity

Cut point	Sensitivity	Specificity	Correctly Classified	LR+	LR-
(>= 3)	100.00%	0.00%	34.69%	1.0000	
(>= 5)	100.00%	9.38%	40.82%	1.1034	0.0000
(>= 6)	100.00%	15.63%	44.90%	1.1852	0.0000
(>= 7)	94.12%	40.63%	59.18%	1.5851	0.1448
(>= 8)	**76.47%**	**68.75%**	**71.43%**	**2.4471**	**0.3422**
(>= 9)	76.47%	84.38%	81.63%	4.8941	0.2789
(>= 10)	35.29%	100.00%	77.55%		0.6471
(>= 11)	17.65%	100.00%	71.43%		0.8235
(>= 12)	5.88%	100.00%	67.35%		0.9412
(> 12)	0.00%	100.00%	65.31%		1.0000

Yourden’s J = Sensitivity + specificity -1 = 0.46

Cut off for predicting amputation on basis of MESS is 8

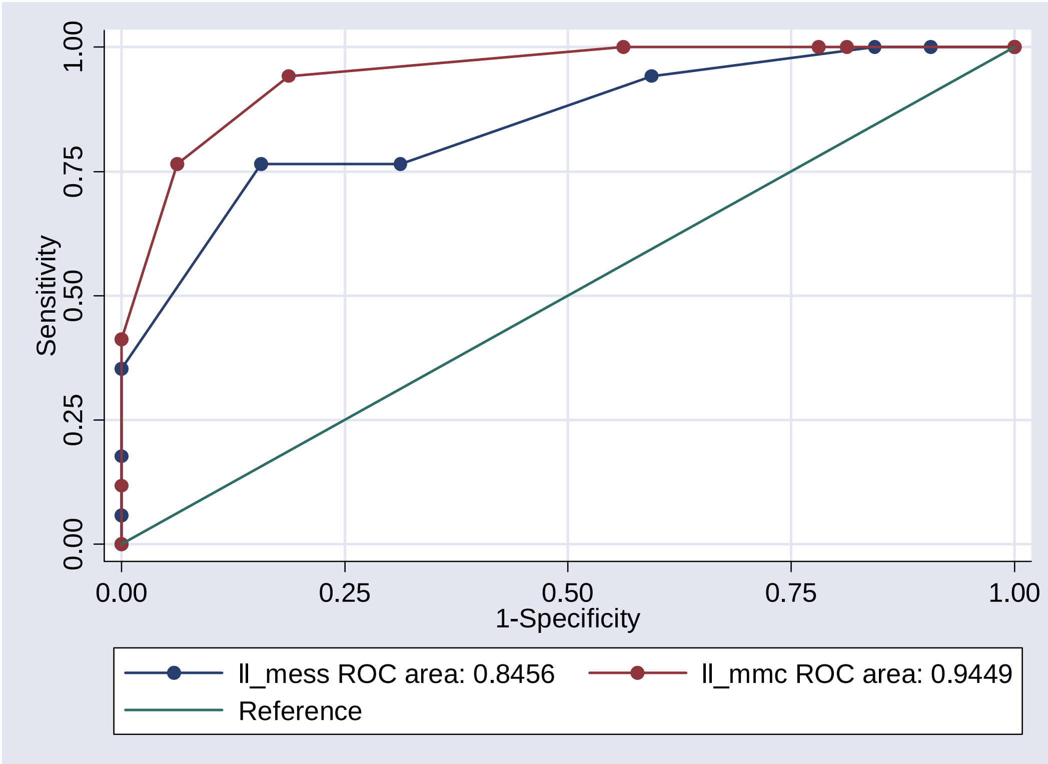
Comparison of Area under the curve (AUC) between the two curves

		ROC	-Asymptotic Normal--		
	Obs	Area	Std. Err.	[95% Conf. Interval]	
ll_MESS	49	0.8456	0.0594	0.72922	0.96195
ll_MMC	49	0.9449	0.0294	0.88730	1.00000

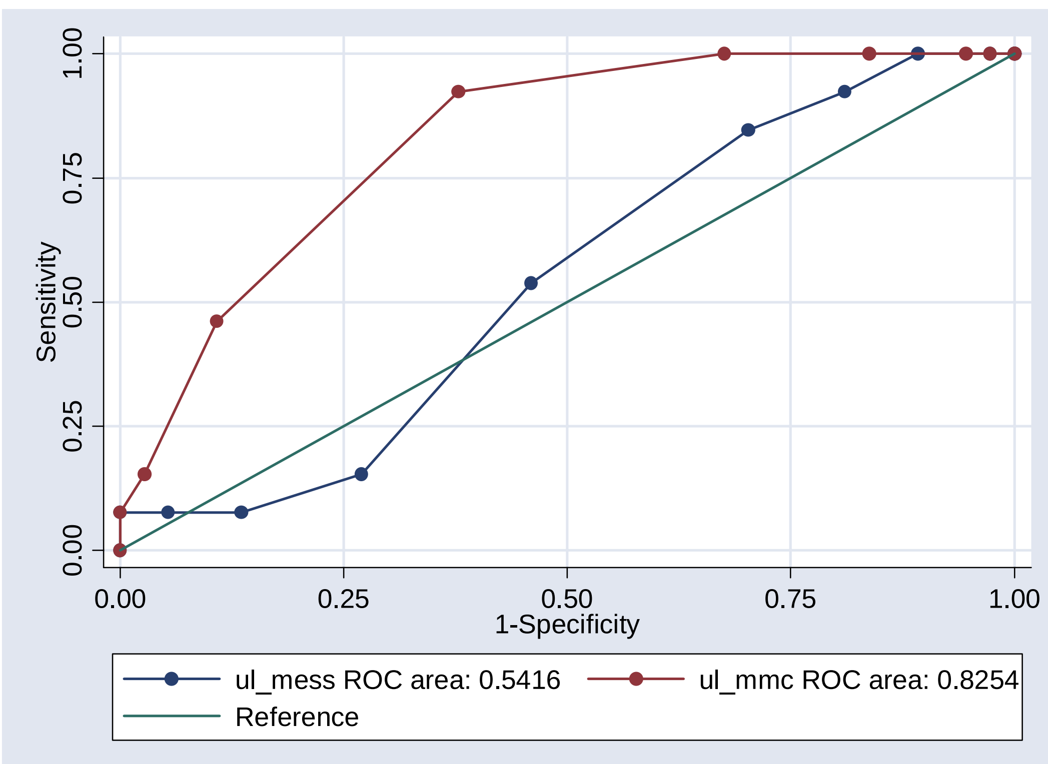
Ho: area(ll_mess) = area(ll_mmc) (ll – Lower limb)

chi2(1) = 2.74 Prob>chi2 = 0.0977

Area under curve is 0.9 which indicates an excellent test of the MMC score for lower limb.



Sensitivity
0.00
0.25
0.50
0.75
1.00
1-Specificity
ll_mess ROC area: 0.8456
ll_mmc ROC area: 0.9449
Reference



Sensitivity
0.00
0.25
0.50
0.75
1.00
1-Specificity
ul_mess ROC area: 0.5416
ul_mmc ROC area: 0.8254
Reference

No of Cases with MMC Score Corresponding MESS

Upper Limb

Score	MESS	MMC
3	1 pt	4 pts
4	1	4
5	4	5
6	6	13
7	12	13
8	16	6
9	8	4
10	3	2
11	1	2
12	1	-

Lower Limb

Score	MMC	MESS
3	-	2 pts
4	-	-
5	6 pts	2
6	1	10
7	7	15
8	13	6
9	11	12
10	9	4
11	7	7
12	5	1

Cases revascularised but amputated within hospitalization period

UL

	MESS	**MMC**
Score 6	1	0
Score 7	1	0
Score 8	0	0
Score 9	0	2
Score 10	0	0
Score 11	1	1
Score 12	0	0
Total	**3**	**3**

LL

	MESS	MMC
Score 3	0	0
Score 4	0	0
Score 5	0	0
Score 6	1	0
Score 7	3	0
Score 8	0	1
Score 9	7	3
Score 10	3	6
Score 11	2	5
Score 12	1	2
Total	**17**	**17**

Limb Salvaged

UL

	MESS	MMC
Score 3	4	1
Score 4	3	1
Score 5	4	4
Score 6	9	6
Score 7	7	11
Score 8	5	10
Score 9	3	3
Score 10	2	1
Total	**37**	**37**

LL

	MESS	MMC
Score 3	3	0
Score 5	2	6
Score 6	3	1
Score 7	9	6
Score 8	4	11
Score 9	5	1
Score 10 – 12	0	1
Total	**26**	**26**

With a cut off of 7 for MESS and a cut off of 8 for MMC score for Predicting amputation the following are the sensitivity and specificity

	Sensitivity	Specificity
MMC score	UL 6/7=86%	UL 33/37=90%
	LL 20/23=87%	LL 24/26=92%
MESS	UL 6/12=50%	UL 27/37=72%
	LL 17/23=74%	LL 18/26=70%

No of cases advised primary amputation =12

	No	MMC score	MESS
UL	3	9,10,12	9,7,11
LL	9	9(3 patients)	6(1 pt)
		10(1 pt)	7(3 pts)
		11(2pts)	10(1pt)
		12(3pts)	11(4pts)

Analysis of results and Discussion

Polytrauma as a result of road traffic accidents, industrial accidents, missile injuries with associated vascular injuries pose difficult questions regarding limb salvage or primary amputation.

Combined vascular and skeletal extremity injuries are relatively uncommon, making up 0.2% of all civilian and military trauma. Only 1.5% to 6.5% of all extremity skeletal trauma is associated with an arterial injury of the same extremity, whereas 10% to 73% of all extremity arterial injuries may be associated with skeletal fractures and dislocations (Mattox et al). By the time they are recognized, precious time is lost and the limb salvage countdown has already begun

Extensive and prolonged attempts at limb salvage with complex and severe injuries would actually prove detrimental, if these efforts invariably end up in amputation or even mortality. In this study, three patients with lower limb injuries who had severe injuries, with score of 10, 10 and 11 were attempted revascularization but died in immediate postoperative period, suggesting that primary amputation might have been more appropriate.

Prompt restoration of blood flow within six hours of any extremity vascular injury is the most critical of the many factors that determine limb salvage and function. Clinical and experimental studies consistently demonstrate a direct linear relationship between the time interval to extremity reperfusion and the amputation rate.

Problems with MESS

Wound contamination plays a significant role in graft blowout in postoperative period. Any score should include this factor for predicting limb salvage. In MESS, only with a score of 4 points for soft tissue injury addresses contamination. Any open injury will have some contamination and this is likely to cause wound infection depending on the bacterial load, adequacy of debridement, appropriate antibiotic therapy, achieving primary skin/ soft tissue or muscle cover. Hence any score should give due importance to this aspect of trauma.

MESS emphasizes duration of ischemia to such an extent that even when a cold insensate limb of over 6 hours duration will invariably have a score of 7 or above assuming that the injury is of low energy. This has not been proven in our experience, as limbs upto 10 hrs of low energy trauma with no flow have been revascularised successfully (8 out of 59 lower limbs 13.2%). A cold limb may still have feeble flow in the vessels which maintains patency and some perfusion. When such limbs are revascularised, post operative period may be stormy in view of reperfusion injury.Expert managment with adequate fluids, mannitol, free radical scavengers, correction of metabolic acidosis, can salvage the limb.

Age factor is significant only in extremes of age. Children have increased incidence of vasospasm which may affect outcome of revascularization. Elderly have increased morbidity but limb salvage does not have adverse outcome in elderly in our study and age may not be a factor denying attempt at limb salvage in elderly. Patients in 3^{rd}, 4^{th} , 5^{th} decades do not seem to have any difference in limb salvage when all other factors are the same. Hence age as a factor for limb salvage except in extremes of age does not seem to have any significant influence over outcome of vascular repair.

There is a possibility of observer bias in classifying whether soft tissue injury is low, medium or high energy in MESS. Different scores would be allotted to the same injury by different observers. This can make a difference in predicting limb salvage or amputation.

Transient hypotension may not be noticed in our subset of patients as the time at which they receive primary care may be late. Persistent hypotension may indicate inadequate resuscitation, presence of other systemic injuries which require tackling and preclude revascularization. After hypotension is corrected there is no reason why limb salvage should have an adverse outcome.

Analysis of Upper limb results

In our study, MESS could not predict outcomes in upper limbs whereas MMC score does so with a reasonable sensitivity and specificity. A medium or high energy injury to upper limb may have a score of 7 or 8 MESS but if distal flow is maintained by profunda brachii flow, the limb may survive with thorough debridement and subsequent bypass or an extra anatomical bypass. The upper extremity is more tolerant than the lower limb of deficits in protective sensation, nerve function, length discrepancy and prosthesis for upper limb less satisfactory.

69.7% of upper limb injuries were of moderate grade of severity and also had the highest rate of salvage 69.7%. Out of 18.8% of cases with severe crush in upper limb, 9.4% underwent amputation (p- value=0.00)

Despite having prolonged ischemia time in18 of 53 (33.8%) of cases, only 5 (9.4%) of upper limbs were amputated, indicating that duration of ischemia may not as important as that in LL for limb salvage. Hence irrespective of duration of ischemia, in upper limb it is worthwhile attempting salvage.

18 (33.8%) cases with no Doppler flow at the time of revascularization. Out of this 13(24.4%) cases were salvaged and in all these cases the duration of ischemia was less than 6-10 hrs or had minimal contamination or grade 1 or grade2 severity of injury. This implies that when the other factors were favourable, only then was salvage probable.

15 (28.2%) out of 53 cases had gross contamination and 11(20.7%) of these were salvaged. In this 4 were extra anatomic bypasses which probably gave a good outcome by avoiding infected fields. Extra anatomic bypass should be considered when the native vessel bed is unsuitable for vascular repair because of contamination, devitalized tissue or lack of soft tissue cover. An autogenous vein interposition is tunneled extraanatomically through clean tissue planes from uninvolved proximal and distal portions of the artery, enabling wound management independent of the repair. These statistics indicate that gross contamination has an adverse effect on limb salvage and invariably leads to blowout and ligation or leading to possible amputation.

84.7% (45 out of 53 cases) had either bony or venous or nerve injury along with arterial injury which by itself had less impact on limb salvage but the more severe the injury had multiple bony, venous and or nerve injuries associated with them and had an adverse outcome with potential post op higher morbidity and infection (due to compound comminuted fractures). In 50% of cases where nerve and major vein was injured with fracture, limbs were not salvaged.

In upper limbs, the sensitivity of MMC score is 86% and specificity is 90% in predicting amputation. Comparable sensitivity for MESS is only 50% and specificity is 72% implying that for similar subset of patients, MMC score has better sensitivity and specificity than MESS. Severe crush injury had a 50% possibility of amputation. However despite more than 10 hrs of ischemia, 9 of 13 cases were salvaged (p=0.07).

<u>Analysis of LL results</u>

Out of 30(50.6%) cases with no flow in ankle, 22 (37.2%) lead to amputation. Only six cases could be salvaged and all these cases had low grade injuries and were operated within 6 to 10 hours, indicating that prolonged ischemia with no flow distally carries a considerably increased risk of amputation.

12 (20.5%) of 35 (69.4%) cases despite prolonged ischemia time greater than 10 hours were salvaged. In all these cases there was an intact limb with some flow which perfuses the lower limb. This may be maintaining the distal circulation and preventing thrombosis, which occurs in a state of no reflow. In such a state, the duration of ischemia may not be relevant for predicting limb salvage. In MESS, the ischemia score is doubled, which may not be applicable in those cases mentioned above with some flow and such cases can successfully be revascularised.

Severity of injury determines significantly the outcome of limb salvage as 21(35.5%) out of 26(43.8%) with severe crush injury could not be salvaged despite bypass.

Gross contamination in wounds, with presence of dirt, grit, paint grease etc. also has a high probability of amputation as seen in this study where 17 (28.8%) out of 20 (33.7%) cases lead to amputation within 2 weeks of hospitalization. Though successfully revascularised, the repairs lead to blowout or thrombosed subsequently.

In case the duration of ischemia is less than 6 hours and blood flow is maintained distally to some extent through collaterals, thorough debridement and adequate flap cover for the graft have achieved limb salvage despite contamination.

19 (32.2%) out of 23 (38.8%) injuries which had compound fractures with major nerve and vein injuries lead to amputation. Nerve disruption or crush does not primarily help in predicting limb salvage but indicates the widespread nature of injury. Venous injury causes postoperative edema, bulging out of muscles from fasciotomy wounds and may result in secondary muscle necrosis, blowout of arterial repair.

Sensitivity of MMC score for lower limbs 87% and specificity is 92%. In comparision, sensitivity of MESS is 74% and specificity is 70%.

Post revascularization technical errors can adversely affect limb survival. MESS gives an accurate predictability for limb salvage but not for amputation. This implies that high MESS does not necessarily mean amputation. Many scores of 7 have been salvaged whereas score of 8 invariably lead to amputation in our series. Hence we recommend that a MESS of 8 or more would be more predictive of amputation.

MMC score of 9 or above predicts lower limb amputation invariably as seen by the fact that all those cases primarily amputated. 16 out of 17 lower limbs when secondarily amputated, had a score of >/=9. This score is more applicable for late injuries where some flow is maintaining limb survival and revascularization may be successful if other factors like infection, nerve injury do not influence postoperative or long term limb salvage.

Extensive and prolonged attempts at salvage of extremities with severe and complex injuries may actually harm the patients in a variety of ways, particularly if amputation is the end result. Financial costs, prolonged hospital occupancy, loss of work for the patient permanent disability, death are significantly greater when limb salvage becomes unnecessarily prolonged compared with early amputation.(Vascular trauma Mattox et al, 2nd ed). Combined extremity injuries that ultimately result in limb loss or limb dysfunction can largely be predicted within a few days of injury by a number of prognostic factors that closely relate to outcome. Transected major nerves and Gustilo III C injuries (open comminuted tibiofibular fractures with arterial injuries) are the most common indications for consideration of immediate amputation. Primary amputation without any attempt at limb salvage is reported in 10% to 22% of cases of complex extremity trauma and such immediate amputations account for more than 50% of amputations following these injuries (Eric R Fryberg in Vascular trauma 2nd Ed). In our cases we have advised primary amputation in 13 cases which were clinically found to have extensive injuries not amenable to salvage. The predictive factors are mainly severe crush injuries with extensive soft tissue loss, combined major nerve, venous and bony injuries. When our score was applied to these limbs we found consistently that they had scores above 9 to 12 where as MESS showed wider variation from 6 to 11.

Although no scoring can predict 100% amputation or salvage, the likelihood of limb salvage or amputation can be clearly explained to patients and they will be aware and willing to participate in the rehabilitation or be readied for amputation if needed.
In view of better prosthesis available and more advanced artificial limbs in the offing, amputations may be a viable alternative to save lives rather than attempting salvage in limbs with higher score which may lead to fatal metabolic alterations.

Further study in other determinants of limb salvage needs to be done like evaluating zones of injury in lower limb, which might have a role in predicting amputation.

We have also observed that primary amputation in our institution has always been decided by vascular surgeons, although this decision should always involve and require the assent of the entire team involved in the care of the patient, including the orthopaedicians, plastic surgeons and the family of the patient.

Replantation in the lower extremities remains a controversial issue, because lowerlimb prostheses provide a stable stance and a functional gait; therefore, prosthesis may be more functional than the replanted limb. In our environment, however, patients prefer to have their limbs, even a poorly functional one, rather than have an artificial one.

Conclusion

Extremity trauma continues to challenge vascular surgeons in aspects of deciding as to when amputation or attempt at revascularization is appropriate. MESS in our clinical setup was found to be inadequate in this crucial decision and thus MMC score was evolved. This score has a high sensitivity and specificity in predicting upper and lower limb amputation as compared to MESS and can be applied to prevent futile and unnecessary attempts at salvage. MMC score has a high sensitivity and specificity for both upper and lower limbs. However lower limb sensitivity is higher than for upper limb, implying that predicting amputation in lower limb is more accurate with this score. The score is simple and can be easily applied in the emergency room with a hand held Doppler instrument. MESS has been found to be ineffective in many studies and predicting amputation only on MESS would be inadvisable. Further validation from other centers is required for uniform adaptation of the MMC score.

With increasing involvement of vascular surgeons in limb salvage or for decision making for primary amputation, a vascular trauma score would help in arriving at a consensus for individual surgeons to achieve a common goal.

References

1. Objective criteria accurately predict amputation following lower extremity trauma. Johansen K, Daines M, Howey T, Helfet D, Hansen ST Jr. J Trauma. 1990; 30: 568 – 73.

2.. Severe open fractures of the lower extremity: a retrospective evaluation of the Mangled Extremity Severity Score (MESS). . McNamara MG, Heckman JD, Corley EG J Orthop Trauma. 1994; 8: 81 – 7.

3. **.** The mangled extremity syndrome (MES): a severity grading system for multisystem injury of the extremity. Gregory RT, Gould RJ, Peclet M, Wagner JS, Gilbert DA, Wheeler JR. J Trauma. 1985; 25: 1147 – 50.

4. Salvage of lower extremities following combined orthopedic and vascular trauma. A predictive salvage index. Howe HR Jr, Poole GV, Clark T, Plonk GW, Koman LA, Pennell TC. Am Surg. 1987; 53: 205 – 8.

5. Limb Salvage Versus Traumatic Amputation: A Decision Based on a Seven-Part Predictive Index. Russell WL, Sailors DM, Whittle TB, et al. Ann Surg 213: 473-481, 1991.

6. Extremity vascular trauma in civilian population: a seven-year review from North India. Menakuru SR, Behera A, Jindal R, Kaman L, Doley R, Venkatesan R. Injury. 2005 Mar;36(3):400-6.

7.Amputation versus limb salvage. Tornetta P 3rd, Olson SA. Instr Course Lect. 1997;46:511-8. Kings County Hospital Center, SUNY Health Science Center at Brooklyn, USA Am J Surg. 1996 Nov;172(5):569-73; discussion 573-4.

8. The futility of predictive scoring of mangled lower extremities.Bonanni F, Rhodes M, Lucke JF. J Trauma. 1993; 34: 99 – 104.0.

9. Outcome and utility of scoring systems in the management of the mangled extremity. Durham RM, Mistry BM, Mazuski JE, Shapiro M, Jacobs D. Am J Surg. 1996; 172: 569 – 74.

10. Mangled extremity severity score: an accurate guide to treatment of the severely injured upper extremity. J Orthop Trauma. 1994 Aug;8(4):282-5. Slauterbeck JR, Britton C, Moneim MS, Clevenger FW. Department of Orthopaedics, University of New Mexico Hospital, Albuquerque.

11. The mangled extremity syndrome (M.E.S.): a severity grading system for multisystem injury of the extremity : J Trauma. 1985 Dec;25(12):1147-50. Gregory RT, Gould RJ, Peclet M, Wagner JS, Gilbert DA, Wheeler JR, Snyder SO, Gayle RG, Schwab CW

12. Arterial injury in the lower limb from blunt trauma. Faris IB, Raptis S, Fitridge R Vascular Surgery Unit, Royal Adelaide Hospital, Adelaide, South Australia, Australia

13. Popliteal artery and trifurcation injuries: is it possible to predict the outcome? Eur J Vasc Surg. 1994 Mar;8(2):226-30. Lazarides MK, Arvanitis DP, Kopadis GC, Tsoupanos SS, Dayantas JN. Department of Vascular Surgery, Athens General Hospital, Greece. J Orthop Trauma. 1994 Dec;8(6):527.

14. Lower Extremity Limb Salvage: Decision Making & Technical Challenges Samuel G. Agnew, M.D., F.A.C.S. Associate Professor of Orthopaedic Traumatology at the University of Florida Health Science Center / Jacksonville

15. Practice Management Guidelines for Penetrating Trauma to the Lower Extremity

The EAST Practice Management Guidelines Work Group: Abenamar Arrillaga, MD, Greenville Memorial Hospital, Greenville, SC, Raymond Bynoe, MD, Richland Memorial Hospital, Columbia, SC, Eric R. Frykberg, MD, University of Florida Health Science Center, Jacksonville, FL, Kimberly Nagy, MD, Cook County Hospital, Chicago, IL

16 Vascular Injuries Near the Knee: An Updated Series and Overview of the Problem. . Snyder WH (Surgery 91: 502-506, 1982 III)

17. Predictive validity testing of severely injured limb scoring systems : Mohsen Karami, MD; Mir Mostafa Sadat, MD; Hassan Tavakkoli, MD; Morteza Taghavi, MD; and Mohammad Reza Golbakhsh, MD, Spine and Orthopedic Research Center (SSRC), Department of Orthopedics, Department of Surgery Sina Hospital, Tehran University of Medical Sciences, Tehran, Iran

18.Critical evaluation of mangled extremity severity scoring system in Indian patients. .Sharma S, Devgan A, Marya KM, Rathee N: Department of Orthopaedics, Paraplegia and Rehabilitation, Postgraduate Institute of Medical Sciences, Rohtak 124001, Haryana, India.

19.Therapeutic approach in vascular injuries of the lower extremity: Amputation or limb salvage] [Article in Turkish] Ozal E, Us MH, Bingol H, Oz BS, Kuralay E, Tatar H. Gulhane Askeri Tip Akademisi, Kalp ve Damar Cerrahisi, 06018 Etlik, Ankara.

20. A prospective evaluation of the clinical utility of the lower-extremity injury-severity scores. Bosse MJ, MacKenzie EJ, Kellam JF, Burgess AR, Webb LX, Swiontkowski MF, Sanders RW, Jones AL, McAndrew MP, Patterson BM, McCarthy ML, Cyril JK.

Department of Orthopaedic Surgery, Carolinas Medical Center, Charlotte, NC 28232-2861, USA.

Name	Limb	Age/Sex	Date	Severity of injury
Ramasamy	Lower Limb	8/M	28/8/04	3
Vijayan	Upper limb	70/M	10/4/2004	3
Muniratnam	Lower Limb	38/M	16/9/04	3
Nityanandan	Lower Limb	36/M	15/10/04	3
Arumugam	Lower Limb	42/M	16/10/04	2
Babu	Upper limb	45/M	8/11/2004	2
Kali	Lower Limb	23/M	15/11/04	2
Rafi	Lower Limb	35/M	16/11/04	3
Dhanraj	Upper limb	23/M	20/11/04	2
Perumal	Lower Limb	35/M	26/11/04	2
Rajendran	Upper limb	40/M	20/12/04	1
Kuppan	Lower Limb	20/M	26/12/04	1
Tamilarasan	Upper limb	18/M	4/1/2005	2
Yesu	Lower Limb	40/M	16/1/05	1
Vasanti	Lower Limb	30/F	20/1/05	2
Manohar	Upper limb	45/M	28/01/05	1
Kanakaraj	Lower Limb	21/M	12/2/2005	2
Perumal	Lower Limb	28/M	14/4/05	3
Sundarambal	Upper limb	60/F	29/4/05	2
Munisamy	Upper limb	19/M	7/5/2005	2
Devasiri	Upper limb	9/M	7/5/2005	1
Ravi	Upper limb	35/M	7/5/2005	2
Durairaj	Upper limb	14/M	30/4/05	2
Harikrishnan	Upper limb	22/M	29/4/05	2
Moorthy	Upper limb	10/M	30/5/05	2
Palani	Lower Limb	21/M	7/6/2005	2
Vijayakumar	Lower Limb	24/M	12/6/2005	1
Mahash	Upper limb	28/M	17/6/05	1
Rajeshwari	Upper limb	35/F	18/6/05	2
Albert	Lower Limb	35/M	9/7/2005	2
Govindan	Upper limb	43/M	21/7/05	3
Indrani	Lower Limb	21/F	3/8/2005	3
Thangapandi	Lower Limb	14/M	8/8/2005	1
Vasudevan	Lower Limb	21/M	10/8/2005	3
Basha	Lower Limb	25/M	2/8/2005	2
Ravindran	Upper limb	52/M	8/9/2005	2
Anandan	Lower Limb	22/M	14/9/05	3
Babu	Lower Limb	45/M	18/9/05	2
Kasinadan	Lower Limb	40/M	21/9/05	2
Charles	Lower Limb	45/M	21/9/05	2
Rajeshwari	Upper limb	20/F	24/9/05	2
Ravi	Lower Limb	37/M	29/9/05	3
Maulana	Upper limb	7/M	4/10/2005	2
Leban ray	Lower Limb	7/M	4/10/2005	2
Nizamuddin	Upper limb	36/M	15/10/05	2
Karthik	Upper limb	23/M	3/11/2005	2
Chakarapani	Upper limb	27/M	5/11/2005	2
Chandrasekar	Upper limb	55/M	8/11/2005	2
Ajit kumar	Lower Limb	31/M	16/11/05	2
Louisraj	Upper limb	36/M	30/11/05	2

Kesavan	Upper limb	25/M	13/1/06	2
Babu	Upper limb	38/M	4/1/2006	2
Vijayakumar	Upper limb	26/M	4/1/2006	3
Shankar	Lower Limb	50/M	6/1/2006	3
Murugan	Lower Limb	20/M	26/3/06	2
Ravikumar	Upper limb	24/M	28/3/06	2
Nagraj	Lower Limb	21/M	30/3/06	2
Samuel	Upper limb	40/M	12/4/2006	3
Dandayudapani	Lower Limb	24/M	14/4/06	3
Sekar	Upper limb	28/M	20/4/06	2
Dinesh	Lower Limb	15/M	26/4/06	2
Kandan	Lower Limb	26/M	11/5/2006	3
Anandraj	Upper limb	30/M	20/5/06	2
Mahiyamsantosham	Upper limb	32/M	28/5/06	3
Senthilkumar	Lower Limb	17/M	12/6/2006	2
Sekar	Lower Limb	19/M	26/6/06	2
Rajivgandi	Lower Limb	28/M	20/6/06	3
Rajesh	Upper limb	25/M	26/6/06	2
Rajendran	Lower Limb	45/M	1/7/2006	2
Sasi	Upper limb	27/M	4/7/2006	2
Damodaran	Lower Limb	27/M	7/7/2006	3
Karthik	Upper limb	10/M	15/7/06	2
Prakash	Lower Limb	17/M	13/7/06	2
Kannaiah	Lower Limb	26/M	27/7/06	2
Mani	Lower Limb	40/M	29/7/06	3
Krishnaveni	Upper limb	62/F	5/8/2006	2
Robin	Upper limb	8/M	2/8/2006	2
Poovarasan	Upper limb	16/M	15/8/06	2
Sowbagya	Upper limb	8/F	9/9/2006	2
Anthony	Lower Limb	43/M	16/9/06	2
Kumar	Upper limb	40/M	19/9/06	2
Manivannan	Upper limb	38/M	27/9/06	1
Gopi	Lower Limb	12/M	3/10/2006	2
Rajesh	Lower Limb	24/M	12/10/2006	3
Kuppan	Lower Limb	55/M	21/10/06	2
Mani	Lower Limb	18/M	12/11/2006	2
Dravid	Upper limb	18/M	19/11/06	3
Kanakaraj	Lower Limb	42/M	22/11/06	2
Sasikala	Upper limb	16/F	27/11/06	2
Karunakaran	Lower Limb	12/M	4/12/2006	2
Barathi	Upper limb	21/M	11/12/2006	2
Kumaresan	Upper limb	30/M	24/12/06	2
Barkat	Upper limb	21/M	19/12/06	2
Visvapadam	Lower Limb	31/M	25/12/06	2
Sridar	Upper limb	27/M	15/1/07	3
Vasantakumar	Upper limb	8/M	18/1/07	2
Sarathi	Upper limb	23/M	19/1/07	3
Kesavan	Lower Limb	40/M	29/1/07	2
Tirumavalavan	Lower Limb	40/M	6/2/2007	3
Sarasu	Upper limb	40/F	10/2/2007	2

Primary amputation

Rajamanikam	Lower limb	49/M	23/11/2005	3
Ramanuja	Upper limb	35/F	27/11/05	3
Suman	Lower limb	21/M	12/2/2006	3
Chakravarthy	Upper limb	50/M	19/2/06	3
Kumar	Lower limb	35/M	24/2/06	3
Mani	Lower limb	40/M	10/3/2006	3
Tirunavukarasu	Lower limb	35/M	13/04/06	3
Selvam	Lower limb	25/M	14/4/06	3
Suryamurthy	Lower limb	51/M	15/6/06	3
Ramalingam	Lower limb	32/M	13/9/06	3
Jayaseelan	Lower limb	50/M	24/9/06	3
Kalyanamurthy	Upper limb	48/M	12/10/2006	3

Duration of ischemia in hrs	Doppler flow	Degree of Contamination	Associated injuries
2	3	2	2
2	1	0	0
3	1	1	1
3	1	1	2
1	1	1	1
2	2	1	0
1	2	1	1
2	3	1	1
1	0	1	1
2	1	1	2
3	1	2	2
2	1	0	1
3	1	2	2
2	1	1	0
3	1	2	1
2	1	2	0
2	1	1	1
3	2	1	1
3	2	1	1
2	1	1	2
1	1	0	1
1	1	0	1
2	2	1	1
1	1	0	1
1	1	1	1
3	1	1	0
2	1	0	1
1	2	1	1
3	1	1	1
2	2	1	1
3	2	2	1
2	2	2	2
3	0	1	0
3	2	1	1
3	1	2	2
3	0	1	1
3	2	2	0
3	1	1	1
3	0	1	1
2	2	1	1
2	1	1	2
3	2	2	1
2	1	1	1
1	0	1	1
2	1	1	1
2	1	2	1
3	1	1	2
3	1	2	0
2	1	1	2
3	1	2	0

1	1	2	1
1	0	1	1
1	0	1	1
2	1	2	1
3	0	2	0
2	1	1	1
3	1	0	2
1	2	1	1
1	3	1	1
2	1	1	2
1	1	1	0
3	2	1	1
3	1	2	1
2	1	1	1
2	2	1	1
3	2	2	2
3	1	2	2
2	1	2	1
2	1	1	2
2	2	0	1
3	2	2	2
2	1	1	0
3	1	1	1
2	2	1	1
3	2	0	2
3	0	2	1
2	1	1	1
3	1	0	1
0	3	1	1
3	2	1	1
3	1	1	1
1	0	1	0
3	1	2	1
3	0	1	1
3	1	2	1
3	1	1	1
2	2	1	1
2	2	2	1
3	1	1	1
3	0	1	1
3	1	1	0
2	2	1	1
2	2	1	1
1	2	1	1
2	2	1	1
1	1	1	1
3	1	1	2
3	2	0	2
3	2	1	2
3	1	1	2

3	0	2	1
3	0	2	2
1	2	1	2
1	2	1	2
1	2	2	2
1	2	2	1
1	2	2	1
3	2	1	2
3	2	2	2
3	2	2	2
3	2	2	2
3	2	2	2

Total MMC score	Skeletal/soft tissue inj	Ischemia	Shock	Age	MESS
12	3	6	1	0	10
7	4	4	0	1	9
8	4	4	0	1	9
10	4	4	0	1	9
6	3	4	0	1	8
7	3	4	0	1	8
7	3	4	0	0	7
10	3	4	0	1	8
5	2	1	0	0	3
8	3	4	0	1	8
9	2	4	0	1	7
5	2	4	0	0	6
10	3	4	0	0	7
5	2	4	0	1	7
9	3	4	0	0	7
6	2	2	1	0	5
7	2	4	1	0	7
10	3	6	1	0	10
9	2	6	0	2	10
8	3	4	1	0	8
4	1	2	0	0	3
5	1	2	0	0	3
8	2	4	1	0	7
5	2	2	0	0	4
6	2	2	0	0	4
7	1	4	1	0	6
5	1	4	0	0	5
6	1	1	1	1	4
8	2	4	0	0	6
8	2	4	1	0	7
11	3	6	1	1	11
11	4	6	2	0	12
5	2	1	0	0	3
10	4	6	1	0	11
10	3	4	0	0	7
7	2	4	2	0	8
10	1	6	0	0	7
8	2	4	0	1	7
7	1	4	0	1	6
8	2	6	0	1	9
8	3	2	0	0	5
11	4	4	0	1	9
7	2	4	0	0	6
5	1	2	0	0	3
7	2	4	0	1	7
8	2	4	0	0	6
9	1	4	0	0	5
8	2	4	0	1	7
8	2	4	0	1	7
8	2	4	0	0	6

7	3	2	0	0	5
5	3	2	1	0	6
6	2	4	0	0	6
9	2	4	0	0	6
7	2	4	0	0	6
7	3	4	0	0	7
8	2	4	0	0	6
8	2	4	1	0	7
9	2	4	0	0	6
8	1	4	0	0	5
5	1	2	0	0	3
10	3	6	0	0	9
9	2	4	0	0	6
8	3	4	0	0	7
8	3	4	1	0	8
11	3	6	0	0	9
11	3	6	0	0	9
8	3	4	0	0	7
8	3	6	0	0	9
7	3	4	0	0	7
12	4	6	0	0	10
6	3	4	0	0	7
8	3	6	0	0	9
8	3	6	0	0	9
10	3	6	0	0	9
8	2	4	0	0	6
7	3	4	0	0	7
7	2	6	0	0	8
7	2	4	0	0	6
9	2	4	0	0	6
8	1	4	0	1	6
3	1	1	0	0	2
9	3	6	0	0	9
8	3	4	0	0	7
9	2	3	1	0	6
8	2	3	0	0	5
9	2	4	0	0	6
9	2	4	0	0	6
8	2	4	0	0	6
7	3	4	0	0	7
7	3	4	0	0	7
8	2	6	1	1	10
8	2	6	0	0	8
7	2	6	0	0	8
9	3	6	0	0	9
6	2	4	0	0	6
10	4	6	0	0	10
9	3	6	1	1	11
11	3	6	1	1	11
9	2	4	0	1	7

9	4	2	1	0	7
10	4	4	0	1	9
9	3	3	1	0	7
9	3	3	1	0	7
10	4	3	0	0	7
9	4	3	1	0	8
9	4	3	1	0	8
11	4	6	1	0	11
12	4	6	0	0	10
12	4	6	1	0	11
12	4	6	1	0	11
12	4	6	1	0	11

Outcome
Expired
Salvaged
Amputation
Salvaged
Salvaged
Salvaged
Salvaged
Blowout/Salvaged
Salvaged
Salvaged
Amputation
Salvaged
Blowout/Salvaged
Salvaged
Amputation
Salvaged
Salvaged
Expired
Graft failure/Salvage
Salvaged
Salvaged
Salvaged
Blowout/Salvaged
Salvaged
Salvaged
Blowout/Salvaged
Salvaged
Salvaged
Salvaged
Salvaged
Amputation
Expired
Salvaged
Expired
Amputation
Salvaged
Amputation
Salvaged
Salvaged
Salvaged
Salvaged
Amputation
Salvaged
Salvaged
Salvaged
Salvaged
Blowout/Salvaged
Salvaged
Salvaged
Salvaged

Salvaged
Salvaged
Salvaged
Salvaged
Salvaged
Salvaged
Thrombosed/salvaged
Thrombosed/salvaged
Salvaged
Salvaged
Salvaged
Amputation
Salvaged
Salvaged
Salvaged
Amputation
Amputation
Salvaged
Salvaged
Salvaged
Amputation
Salvaged
Salvaged
Salvaged
Amputation
Salvaged
Blowout/Salvaged
Salvaged
Salvaged
Thrombosed/salvaged
Salvaged
Salvaged
Amputation
Salvaged
Thrombosed/salvaged
Salvaged
Amputation
Amputation
Salvaged
Salvaged
Salvaged
Salvaged
Thrombosed/salvaged
Salvaged
Salvaged
Salvaged
Salvaged/extraanatomic
Amputation
Expired
Salvaged/extraanatomic